PROBLEMS OF QUALITY

We continue discussing the aspects of reproducibility of the quality of inorganic nonmetallic materials with respect to solving the "composition-structure-property" problem.

UDC 666.3:620.192:681.3.06

CONTROLLING THE QUALITY OF CERAMICS

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Translated from Steklo i Keramika, No. 2, pp. 3 – 4, February, 1999.

Possible approaches to solving the problem of the reproducibility of ceramic products are considered. The insufficient effect of using only statistical methods for this purpose is discussed. A program for investigating the studied object in stages is proposed, which is completed with the development of a mathematical model of the physicochemical processes of ceramic synthesis.

A. B. Belyakov and V. S. Bakunov in [1] touch upon the extremely important problem of reproducibility of the quality of ceramic products. However, this problem is as significant for all high-melting nonmetallic and silicate materials. In view of that, the concepts discussed in the above paper acquire a fundamental and conceptualistic nature for the field of technology. While largely sharing the views of the mentioned authors, we, however, believe that the concept of the instability of quality as a consequence of the probabilistic nature of the processes is not quite adequate to the actual situation.

Apparently, the ability of a production engineer to attain a certain level of reproducibility of ceramics and other articles primarily depends on the attained level of knowledge of the process and the ability to control the process. For one example, it is known from experience in enameled article production that certain types of flaws can arise without any apparent reason, in spite of the stability of the production process, and disappear without any apparent reason as well. The appearance of these flaws is chaotic and probabilistic. However, as information continued to accumulate, a relationship between the seasonal fluctuations in the hardness of the water used in the process and the amount of flaws was established. Next a relationship between the amount of salts in the water, the rheological properties of the enamel coating, and the properties of the melt was established, and this knowledge made it possible to adopt certain measures to prevent the appearance of the defects.

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In the general case, the very essence of the accumulated knowledge can be completely different and as a limiting case can be represented by two options. According to the first option, and object can be investigated as a "black box", i.e., the nature of its reactions to external actions or perturbations is determined with a certain (possibly very high) degree of accuracy. According to the second option, the knowledge can consist in ascertaining the unique cause-and-effect relationships, which results in the development of a mathematical model of the physicochemical process. It is obvious that obtaining each of type of knowledge implies the use of different algorithms.

The information obtained using the above schemes can be equally reliable but not equivalent with respect to the technology, since it offers different control methods with significantly different capabilities to a production engineer. If we accept this concept and assume the logical chain: "quality (reproducibility of properties) — ability to control the process — level of knowledge of the mechanisms — method of obtaining knowledge," then the potential ability of a production engineer to produce high-quality articles is ultimately determined by the choice of the method for acquiring the needed data. Specifically, we believe that the use of the concept of the probabilistic nature of ceramic synthesis and the ensuing research methods are simply determined by an insufficient initial database. This is why a researcher is forced to use "the black box" variant which is universal and therefore has a general nature. The same reason is responsible for the use of the formal mathematical procedures in this case for

0361-7610/99/0102-0037$22.00

planning of experiments and also for data processing and interpretation. This undeniably makes it possible to reduce to a minimum the number of experiments and yet obtain a description of the object behavior for the entire factor space. However, in spite of the abstract nature of this approach, the results obtained in this way are usually of specific and applied nature.

Let us demonstrate our concept on the examples similar to those in [1]. Let us assume that the macrostructure (cross grain, cracks) and the grade of bricks are monitored for a certain time. It is obvious that a sufficiently large number of measurements can be performed to determine with the prescribed probability the error, reliability, and other parameters of the measurements performed. However, although these data evidently constitute an objective picture of the actual situation, they are not very valuable for the production engineer, since they do not offer any new control instruments. This is especially obvious, since it is known that cracks can be produced by excessive moisture of the ceramic mixture, incorrect drying conditions, insufficient grog addition, and many other factors. The same can be said about the cross-grain effect which can be accounted for by a nonuniform weigher operation, moisture in the mixer, incorrect nozzle design, etc. It can be seen from this example that statistical methods can be used to describe a phenomenon, but not to identify its cause. Therefore, the accumulated data as a rule cannot be used to ensure stable product quality.

Another more typical situation can be considered. The authors of the present paper had the occasion to study the effect of the extrusion conditions on the formation of cracks in roof tiles and bricks in the course of drying.

In the first case, the relationship between the mixture composition and crack formation was investigated. To this end, a simple grid Scheffe plan of the third order with a standard postprocessing procedure and plotting of the composition/property diagram isolines was used. This made it possible to identify and locate the optimum regions based on a relatively low number of experimental mixtures, relate the obtained data to cost considerations, and justify the choice of the most suitable composition. However, in spite of the obvious practical value of the described results, they are specific as well, since they establish the existing state within strictly defined limits but do not explain it. Therefore, even slight deviation from the specified conditions, such as a variation in the granular composition of a grog component makes the system behavior unpredictable, and the experiments have to be repeated.

In the second case, the following working hypothesis was used for solving a similar problem. The propensity of the intermediate product to crack formation is higher, the greater the nonuniformity of the pressure distribution inside the bar pressed out of the nozzle section. For a particular press design, this nonuniformity is determined by the friction coefficient of the ceramic mixture against the press walls, the internal friction coefficient of the mixture, and their ratio. It follows from this setting of the problem that primarily the effect of the raw material components on the above listed parameters should be established and then related to the propensity for crack formation. This was also done using the simplex grid Scheffe plan of the third order. As a consequence, the optimum value range for the specified parameters was determined, and the methods for their modification in the required direction were established.

At first glance, the results obtained in the first and the second case can seem identical, but this is not so. In the second case, a model of the process was developed: the mixture properties — the nature of the mixture flow inside the press — the origin of flow nonuniformity — unequal air shrinkage of the product parts subjected during formation to compression and tensile strains — formation of cracks. Moreover, the parameters of the mixture properties which ensure the minimum flaws are determined quantitatively and the methods for accomplishing these parameters are established. Having these data at his disposal, the production engineer can vary the formula and composition of the mixture and other technological parameters for the purpose of obtaining high-quality products with quite predictable and desirable results.

It should be stressed that this approach to the investigation should involve fundamental properties. For instance, in this particular case the friction coefficient of a ceramic mixture against the press wall was determined generally, without taking into consideration the properties of the particular clay (plasticity, dispersion, etc.).

In our opinion, this approach to the technology of silicates was first demonstrated rather obviously in [2, 3]. In these studies K. P. Azarov and co-authors, in analyzing the gas emitted in firing of the glass enamel coating on a steel substrate, suggested considering not the specific components of the investigated system but the abstract components: the solid, liquid, and the gas phases. According to this approach, the interaction between the components in such systems should be related, for example, not to the B_2O_3 content in the enamel or the carbon content in the steel, but to their fundamental properties (viscosity of the liquid phase, surface tensions at the phase boundaries, wetting ability). If a model of the process is constructed on this basis, as we tried to do in [4, 5] with respect to the pinpricks in the primer enamel coat on steel, the entire database of the available fundamental data can be used. For example, an extensive list of published data on the possibility of controlling glass viscosity or the surface tension in glass at the boundary of the gas phase could be supplied with respect to the above example.

Thus, the use of statistical methods in process analysis should be regarded as a forced measure determined by the lack of the initial information regarding the particular object. These methods are expedient in the cases when it is enough

to ascertain the facts; for example, when one has to establish the variation limits of resistance to cold for a particular batch of bricks.

In the event that the researcher has to elucidate the causes of a certain phenomenon and, consequently, a set of possible ways of directing the process as desired to provide for stable product quality, the most expedient is a program consisting of the following research stages: putting forward a working hypothesis for the essence of the considered object; verification of the existence of the cause-and-effect relationship between the events in the system and distinguishing the significant factors; development of the qualitative concept of the physicochemical mechanism of the process; and finally, development of the mathematical model of the process.

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